Federal Aviation Administration

2006 Fort Worth ACO DER Conference

Structural Substantiation of Secondary Composite Structures

By: David Swartz

FAA ACE Policy on Substantiation of Secondary Composite Structures (SCS)*

- Purpose to reduce inconsistencies in substantiating SCS
- Definition of secondary structure is consistent with AC 23-19
  - "… not primary load carrying members, and their failure would not reduce structural integrity … or prevent … continuing safe flight and landing"
  - Mostly for SCS whose failure may poses a threat to persons outside the aircraft
  - Some guidance for non-structural parts whose failure is inconsequential.
  - Examples of Secondary Composite Structure:
    - Fairings
    - Landing Gear Doors
    - Cowlings
    - Radomes
    - Interior structures that do **NOT** carry crash loads

* PS-ACE100-2004-10030, April 2005
At FAA website or contact Lester Cheng:
316-946-4111, lester.cheng@faa.gov

Secondary Composite Structure
Tips on applying the definition:

- Through general wording, the policy memo intentionally relies on DER's to exercise judgment.
- The "continued safe flight and landing" clause in intended to address parts like flight controls that are sometimes composite, but are not in the primary load path. (Policy memo does not apply to flight control surfaces)
- When considering this clause, think of realistic failure scenarios, not just the part vaporizes on the airplane. Ask questions like:
  - Where will the part go? Will it get ingested, hit a critical surface, or make the airplane be controllable?
  - Will the engine continue to run?
  - Will it affect critical systems? (jam flight controls?)

Secondary Composite Structure

- PS-ACE100-2004-1003 is currently limited to Small airplanes (Part 23 and CAR 3)
- Material & process qualification (benchmarking) and controls to ensure part repeatability dependent on SCS criticality
  - Some relief for non-structural parts
- Drawings & specs with sufficient detail to maintain control
- ****Caution***** Material and process specs that are acceptable for secondary structures may not be acceptable for primary structures.
- Static strength substantiation by tests and/or analysis
  - Fatigue & damage tolerance is not required but damage/defect disposition is likely needed for service/factory
- Flammability tests as required by rule
- Lightning protection substantiation remains unchanged

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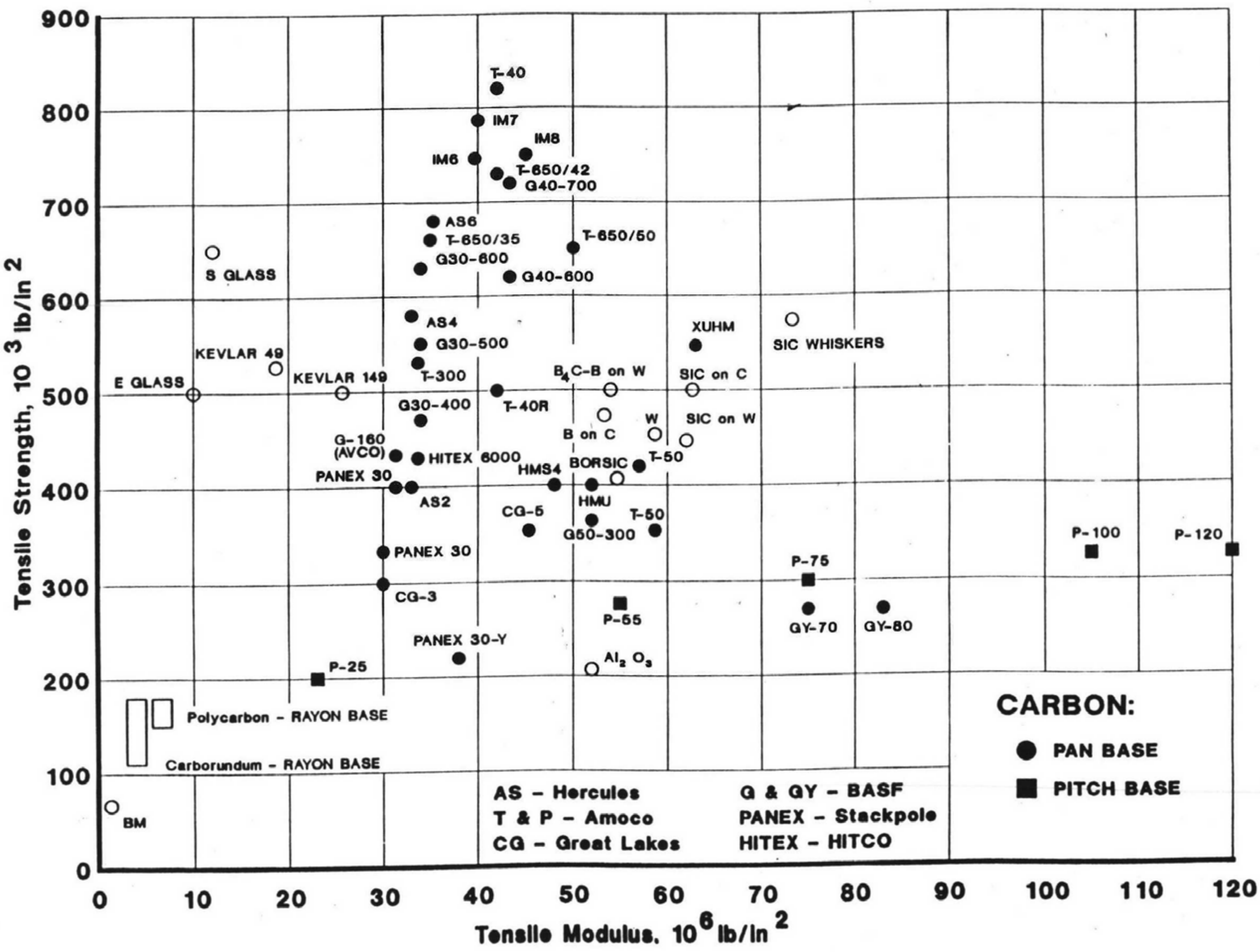
An Example using the Secondary Structure Policy Memo

- Consider a replacement cowling for a small reciprocating engine airplane. (Same cooling geometry as original)
- Applicable Rules:
  - 21.31, Type Design "…specifications, necessary to define…applicable requirements.
  - 23.603 Materials and workmanship " ((c) must … take into account the effects of environmental conditions, such as temperature and humidity, expected in service.)
  - 23.605 Fabrication methods
  - 23.613 Material strength values
  - 23.1181 Designated Fire Zones
  - 23.1193 Cowling and Nacelle

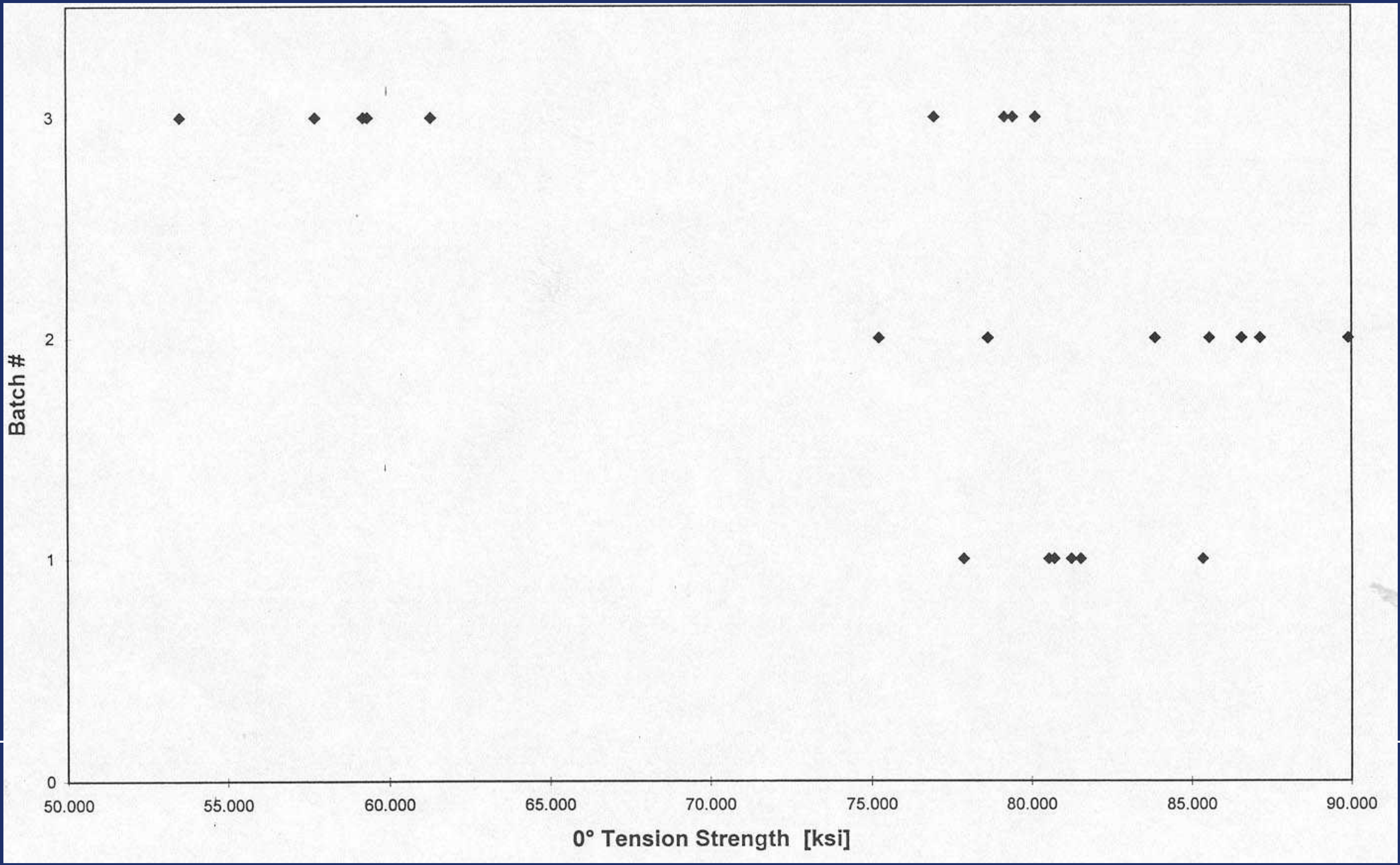
Example using Secondary Structure Policy Memo Testing requirements

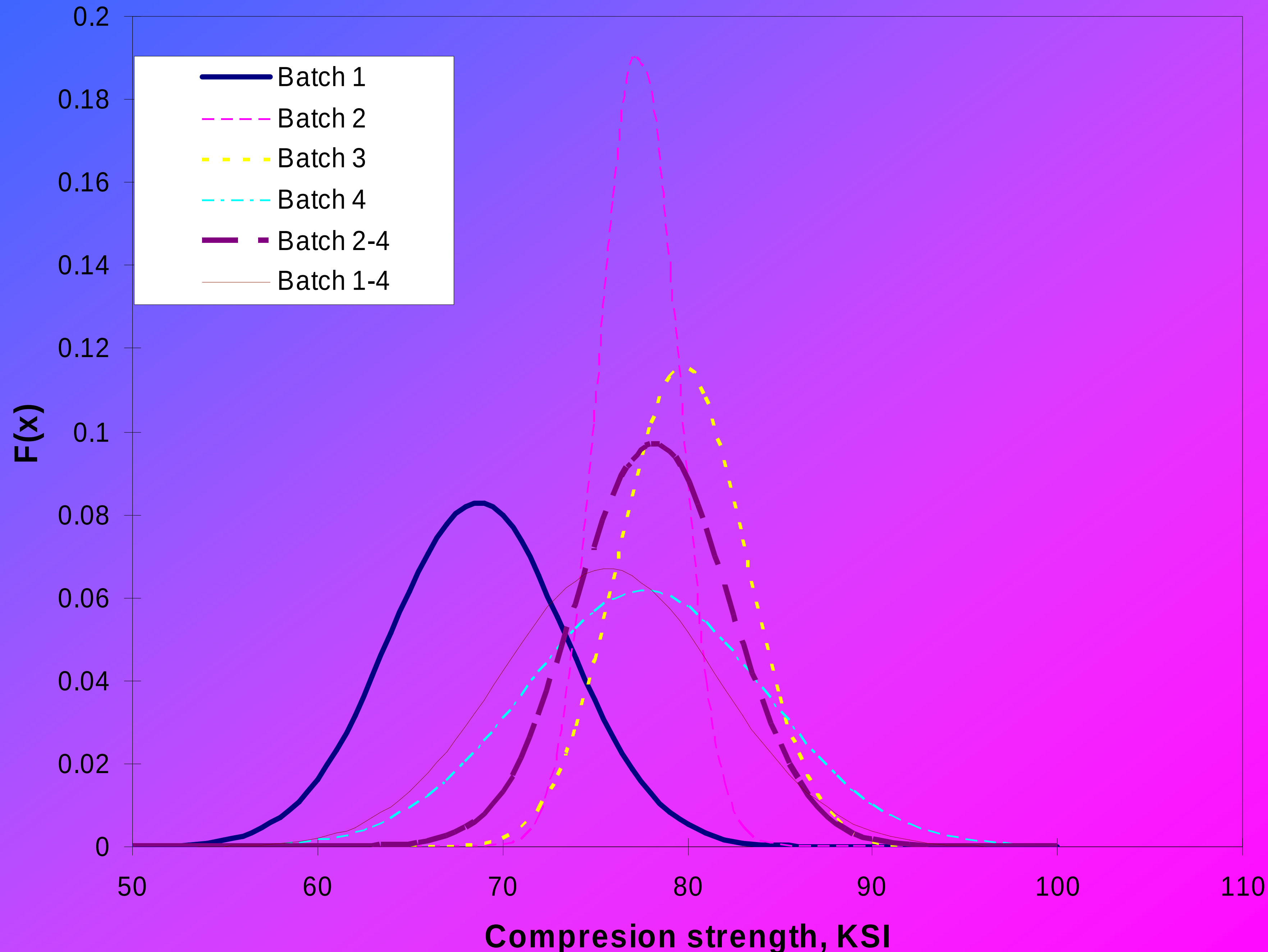
- Burn tests are required by 23.1181. Policy memo clarifies that they need to be done, but doesn't relieve requirements.
- Material Qualification testing. Policy memo allows some relief based on the use of vendor data and judgment in cooperation with the project engineer at the FAA. Often the problem is that all vendor data is not of the same.
  - Some vendors publish data that is statistically based and covers the complete thermal and moisture envelope.
  - Some vendors are principally supporting other industries and do not provide moisture absorption data, variability data or thermal data.
  - The thermal and humidity knock down factors selected will depend on what type of data is available.
  - Often, a material system has never been tested, but the resin and fiber have, but using a different cure process. This can provide a basis for a conservative estimate of properties, but large scale up issues frequently occur.

Tensile Strength and Modulus for Selected Fibers

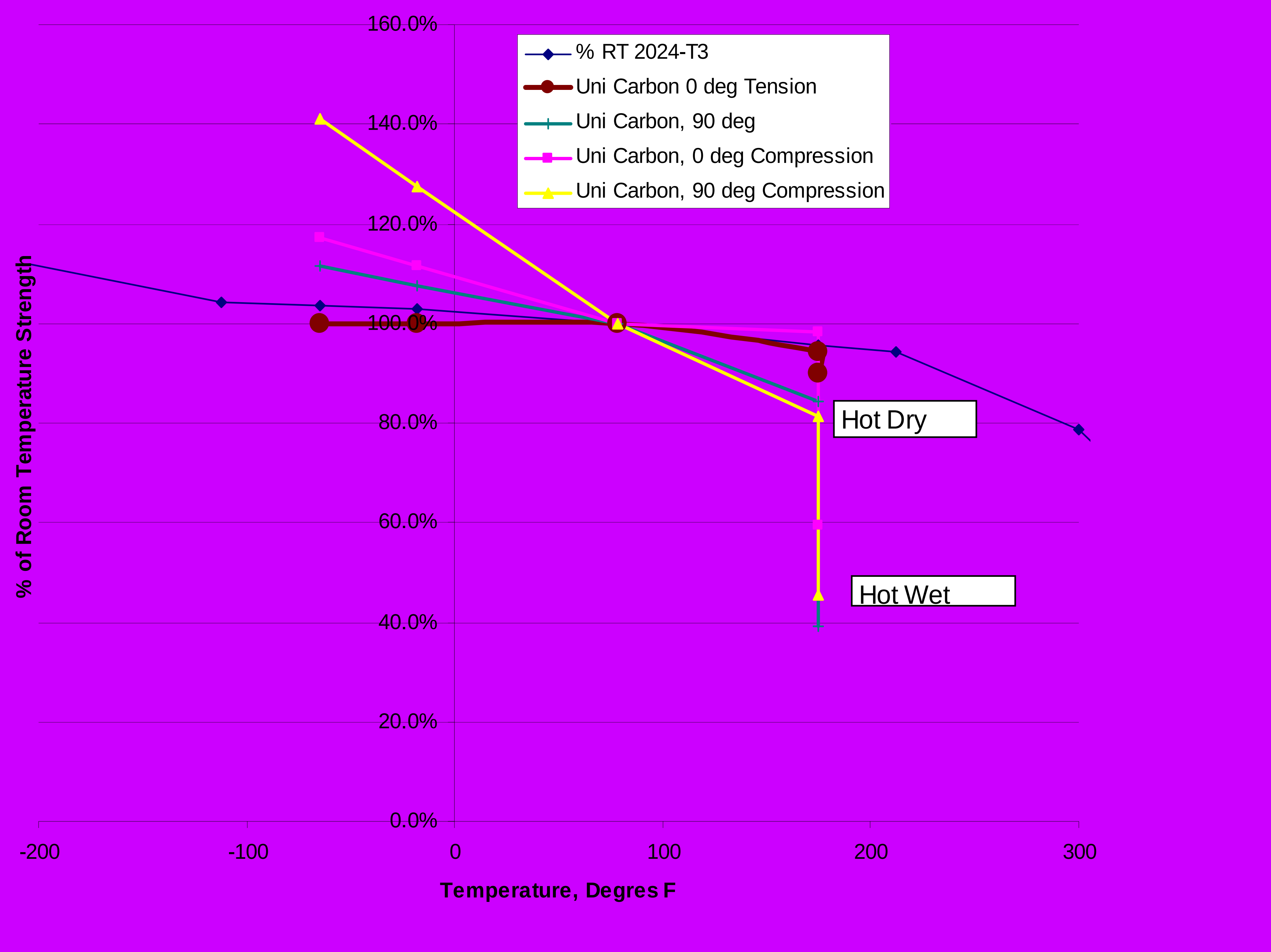


Variability in Tension Results (possibly extreme example)
Hot Wet Fiber Direction Carbon Fabric Plain Weave





Batch 1
Batch 2
Batch 3
Batch 4
Batch 2-4
Batch 1-4
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
F(x)
50
60
70
80
90
100
110
Compression strength, KSI



160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
% of Room Temperature Strength
-200
-100
0
100
200
300
Temperature, Degres F
% RT 2024-T3
Uni Carbon 0 deg Tension
Uni Carbon, 90 deg
Uni Carbon, 0 deg Compression
Uni Carbon, 90 deg Compression
Hot Dry
Hot Wet

A hypothetical example of how you might get a knock down factor

- Known:
  - Have data on the same resin for “B” basis, but using a different fiber. Also, the existing data is for autoclave and the application is vacuum bag process. Oh, by the way, the data is 25 years old and a bunch of minor changes have been made as well. We have some data on another system about what the difference between autoclave and vacuum bag is.

One Approach to get a knock down factor
The Policy Memo does not specify a process, use judgment:

- Here is one Idea, not the only one or the only acceptable one.
  1. Normalize the data by strength/ply
  2. Apply a correction based on the difference in fiber
  3. Apply a correction based on the difference in cure based on the data on the other system.
  4. Make sure they fiber sizing is compatible with the resin
  5. Apply a fudge factor to cover our ignorance.
  6. Test at the full scale to the resulting factor, if you pass, your are done.
  7. If you fail, you can consider doing some additional coupon or element tests to refine the factor, or beef and retest.
  8. Another option is to account for the temperature effect by testing at the full scale at temperature. This is usually less conservative than testing at a factored load level testing

Another example when all you have is limited vendor data

- You are probably looking a a big factor.
- Look at the data and find out from the vendor where the data came from.
- Do you have elevated temperature and humidity effect data?
- If no real data is available from the vendor, you may need to do some limited testing or choose a system for which data exists.
- If the application is non structural, a subjective evaluation of strength at the full scale may be sufficient, if a process spec exists.
- Flammability and lightning still need to be considered depending on the application.

Summary

- The new policy memo allows for some relaxation of data requirements for secondary structure, but relies on judgment being exercised by the DER community
- When in doubt about what a composite material will and won't do, there is no substitute for data and experience. Often the material manufacturers have more than is listed on their web site.

Resin Transfer Molded Thermoplastic/Carbon Fiber

Extreme Composites

Questions?

Safety Philosophy Behind Using Bonded Joints in Critical Applications

- Three legs to assuring a safe bonded joint

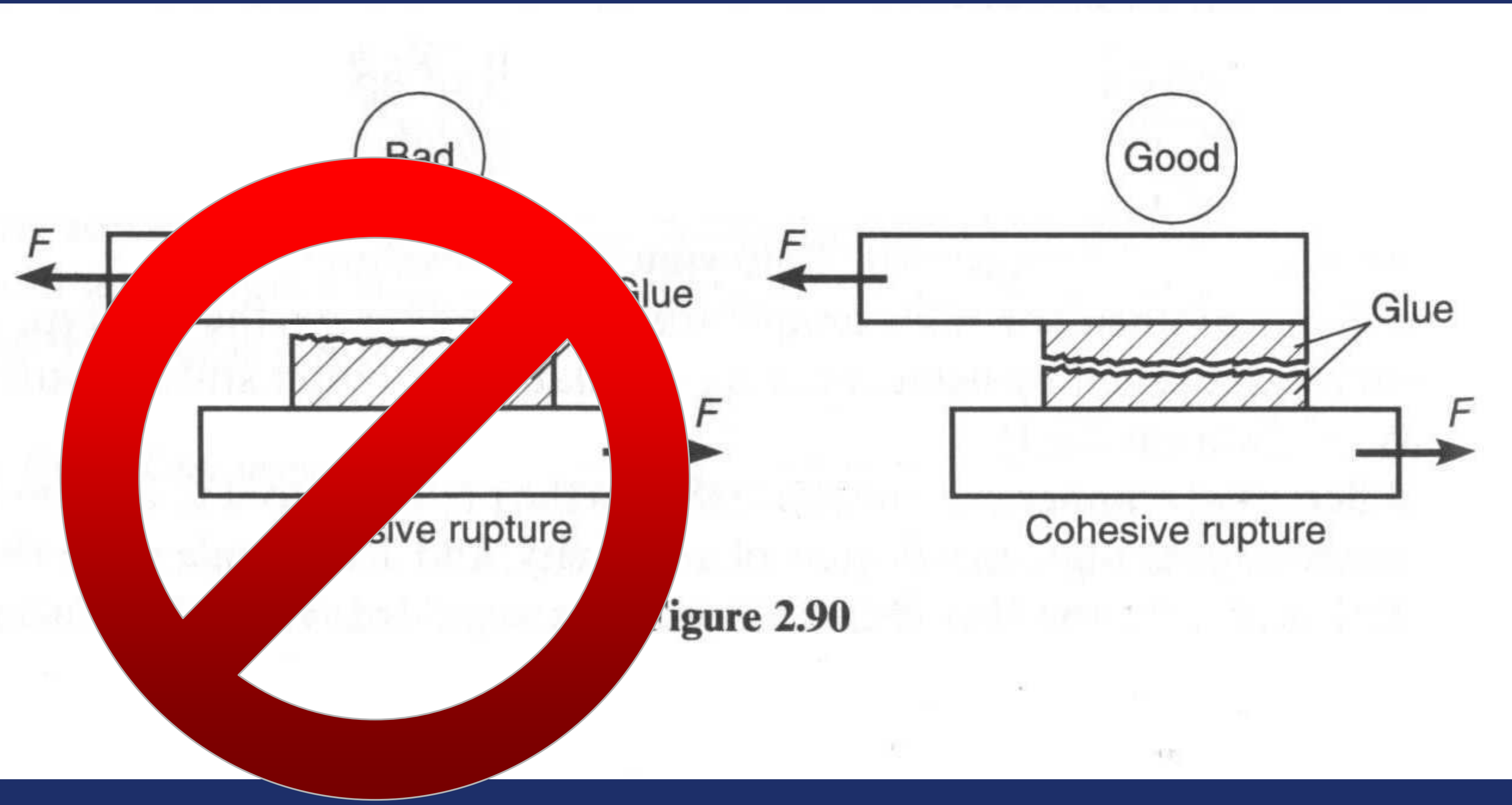
Redundant Structure

- All critical structure that is adhesively bonded should be redundant. (there are exceptions)
- This is accomplished in several ways.
  - Multiple bond lines, each one capable of taking limit load. (limit is the maximum normally expected load in service)
  - Design features capable of stopping a disbond. (i.e. chicken rivets or rib intersections)

Adhesive Joints

- Adhesive Joints can fail in two ways, Adhesively and cohesively. (Adhesive failure is sometimes called interfacial failure)
- **Adhesively is when the glue doesn't stick**
- Cohesive is when the failure is within the glue. (glue on both sides)
- Cohesive failures are predictable based on stress analysis, adhesive failures are not.
- Both failure modes can be bad if they happen at to low a load.
- Adhesive Failure indicates that the surface prep wasn't right ***AND*** that the joint won't last in service.

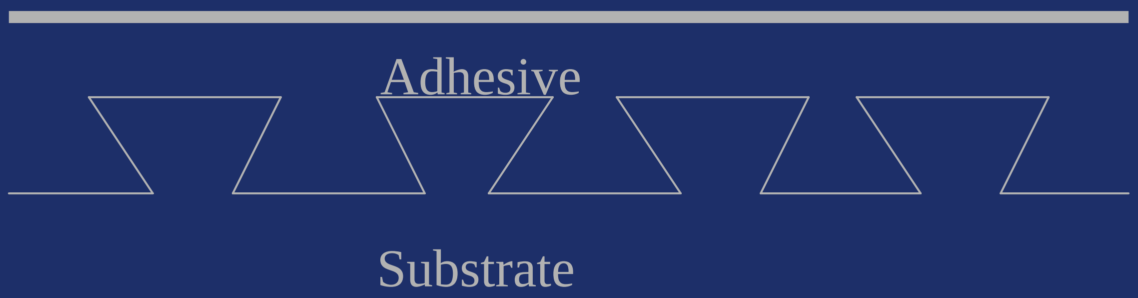
Failure Modes for Adhesive Joints



Just say NO to Adhesive Failures!!!!!

Adhesion

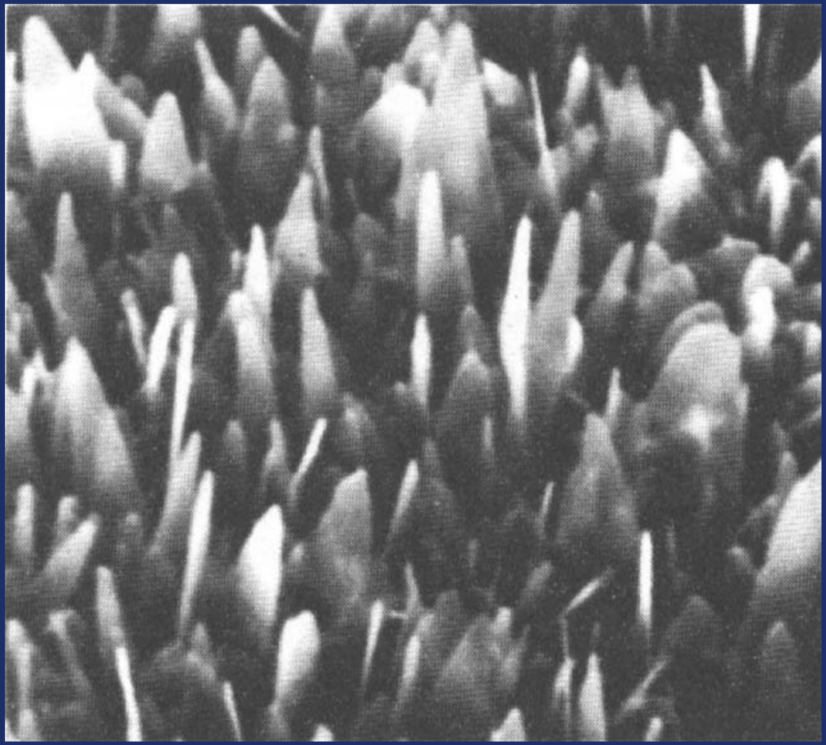
- There are two types of adhesion, mechanical and chemical. (there is some argument in the technical community here)
- Mechanical adhesion occurs when the two materials interlock:



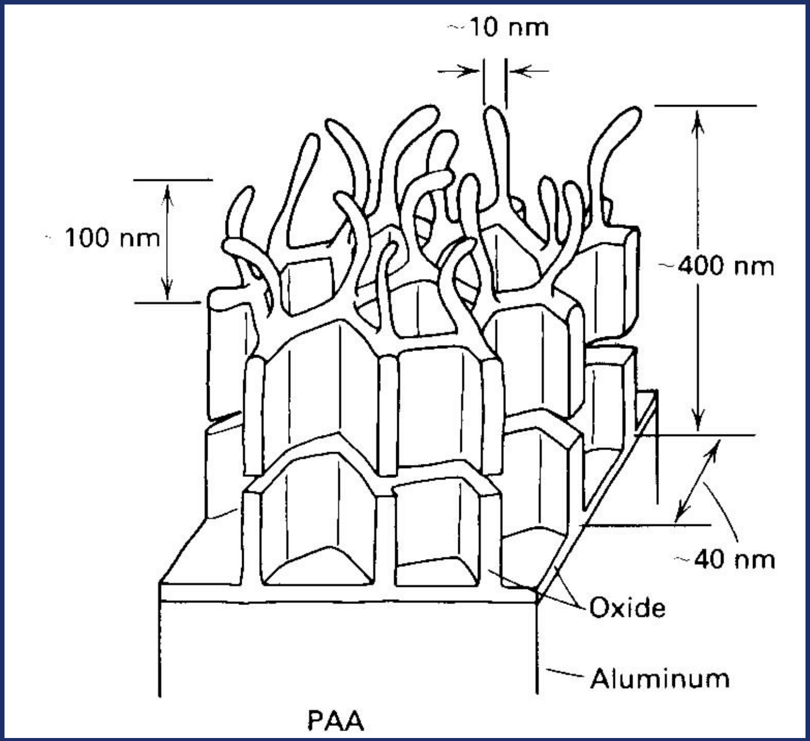
Mechanical Adhesion

- For mechanical adhesion, the surface texture and the direction of sanding are important.
- The Thickness of the Adhesive layer is also very important. (see Module 4)
- Important process parameters:
  - Type of sandpaper
  - Direction of sanding
  - Type and age of grit (old grit can be contaminated and rounded)
  - A surface roughness measurement doesn’t tell the whole story, the shape of the scratches matters.
  - Thickening agents, like microbaloons, flox, cabosil etc. influence the ability of the adhesive to fill the microscopic pours in the surface.

Some Surface Pictures



Picture of Anodized Steel



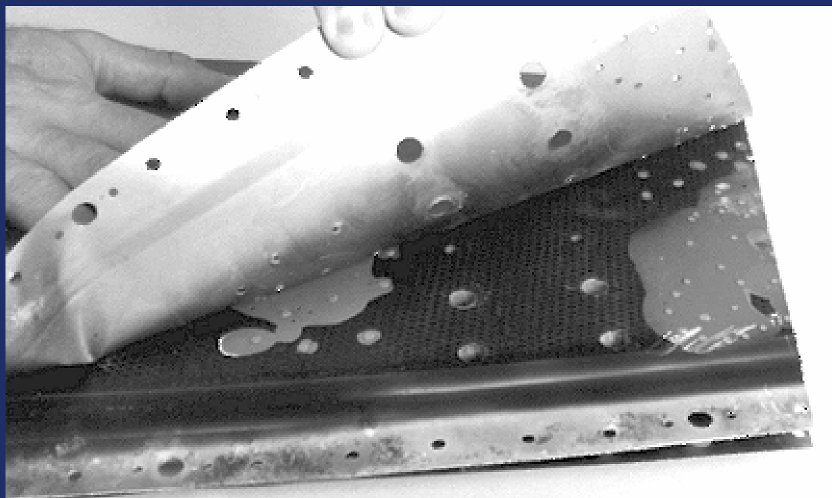
Schematic of Phosphoric Acid Anodized Aluminum Surface

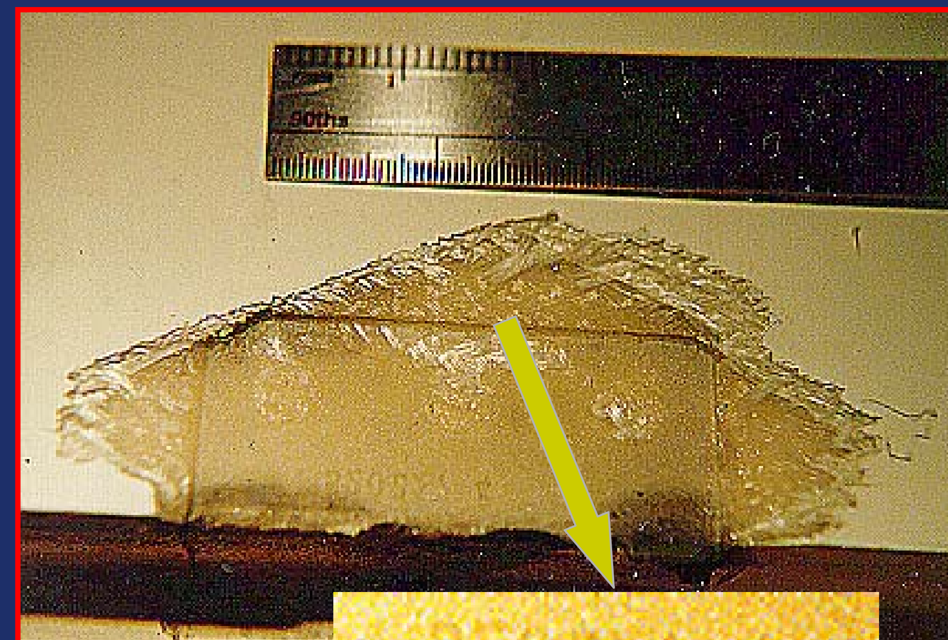
Ref ASM Engineered Materials Handbook Vol. 3, Adhesives and Sealants, ©1990.

Metal Bonding Process Control

- For QA purposes, the wedge peel test is the most common and one of the better tests for adhesion.
- For Phosphoric Acid Anodized (PAA) surfaces, inspection by polarized light using a diffraction gratings can detect fingerprints, and areas where the PAA surface is not uniform or is contaminated
- Priming and bonding should be done promptly to prevent contaminants from getting on the surface, or other oxidation from forming.

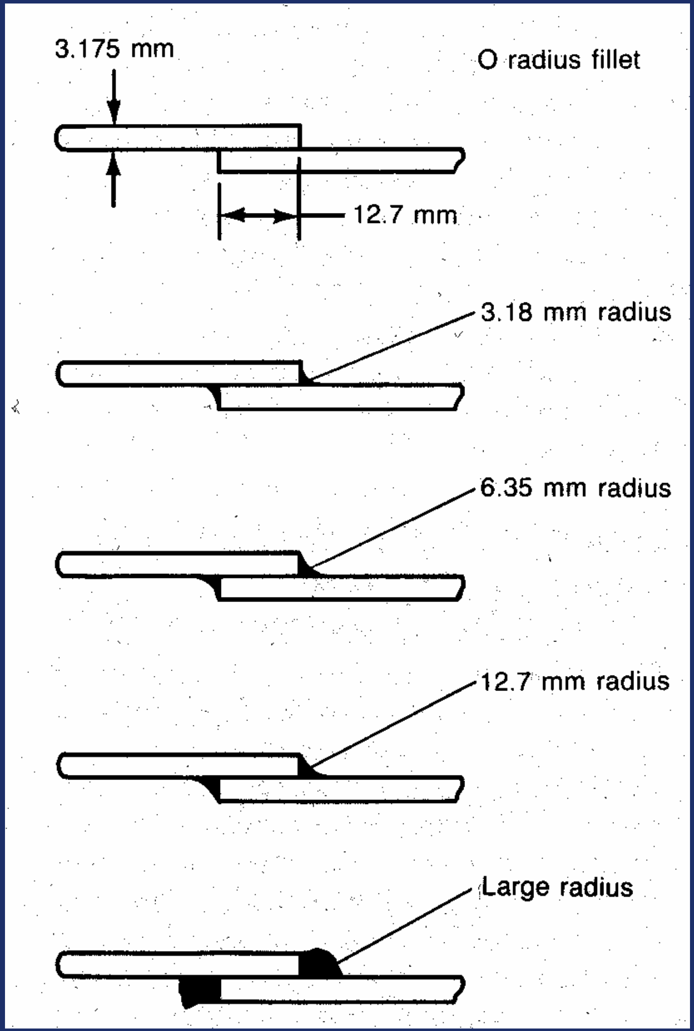
Some Examples of Errors in surface prep in Bonding





Serial Number

Treating the squeeze out (spew)



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Effect of Spew Treatment

Fillet Radius Inches (mm)	Failure Load Pounds	% increase
0 in (0 mm)	1331	----
.13 (3.18)	1553	16%
.25 (6.35)	1823	37%
.50 (12.7)	1894	42%
Large	2267	70%

1) Ref ASM Engineered Materials Handbook Vol. 3, Adhesives and Sealants, ©1990.
2) Data is for .125 thick aluminum adherents and Hysol EA9394 Epoxy Adhesive.
3) All failures are cohesive.
4) Changes in any of the parameters of the joint will change these numbers.